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MILLING METHODS AT THE LEAD-ZINC CONCENTRATOR OF THE INTERNATIONAL SMELTING CO., TOOELE, UTAH

BY

W. J. McKENNA

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UNITED STATES BUREAU OF MINES

MILLING METHODS AT THE LEAD-ZINC CONCENTRATOR OF THE INTERNATIONAL SMELTING CO., TOOELE, UTAH [1]

By W. J. McKenna [2]

INTRODUCTION

This paper, describing the milling practice at the lead-zinc concentrator of the International Smelting Co., is one of a series of papers on milling methods being prepared by the United States Bureau of Mines.

The concentrator is operated as a unit of the International Smelting Co. and is located about 40 miles southwest of Salt Lake City, at Tooele, Utah. The Tooele Valley Railroad, operating between the plant and Warner, Utah, a distance of 6.5 miles, makes connection with both the Union Pacific and Denver & Rio Grande Railroads.

The concentrator operates as a custom lead-zinc mill, treating approximately 1,150 tons per day entirely by flotation methods. The resulting lead and iron concentrates are smelted locally and the zinc concentrates are shipped to the Anaconda Copper Co. plants at Anaconda and Great Falls, Mont.

In general, the concentrator consists of a frame building housing the coarse crushing, fine grinding, flotation, concentrate thickeners, and filter equipment.

WATER

Fresh water is piped a distance of 3 miles from mountain springs to a 412,000-gallon capacity concrete storage tank.

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1 The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6758."

2 One of the consulting engineers, U. S. Bureau of Mines, and concentrator superintendent, International Smelting Co.

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POWER

Electric power is supplied by the Utah Power & Light Co. at 44,000 volts and transformed to 440, 220, and 110 volts for use in the concentrator. Steam power is generated at the centralized smelter power house and distributed to the concentrator at 100 pounds' pressure.

ORE TREATED

The major sources of ore supply have been from the Park City and Bingham, Utah, mining districts. Lesser but important amounts have been received from the Tintic, Frisco, and Ophir, Utah, districts and the adjacent States of Colorado, Idaho, and Nevada. Materials from the above sources include crude sulphide ores and gravity-mill table middlings and slimes.

It is evident that ores shipped from so many different mining districts would vary in general characteristics and metal contents. A typical analysis of a mixture of crude ores and gravity-mill products follows:

Percent				Ounces per ton	
Lead	Copper	Zinc	Iron	Gold	Silver
8.62	0.42	11.23	9.75	0.137	7.10

Owing to the several different ores received, only more or less general descriptions can be given of their mineral contents.

The copper content, while low, is present chiefly as chalcopyrite and tetrahedrite, with minor amounts of covellite and bornite. The lead mineral, galena, varies from the fine-grained steel galena to the coarse crystalline variety, the latter often showing slight surface oxidation. Daily determinations of oxide lead in the mill feed shows an average of 0.10 percent. The precious metals generally follow the copper minerals and galena, although gold is associated with the pyrite to a large extent in most of the ores. Zinc occurs mostly as a true sphalerite, which has a light resin color. The predominating gangue is hard quartzite, although several ores contain soft talc-like gangue which causes considerable difficulty in the settlement of tailing.

Average moisture content of ore receipts is 4.5 percent. Mixing the dry and sticky ores tends to eliminate most of the difficulties experienced in handling them.

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HISTORY OF CONCENTRATOR OPERATIONS

Before presenting the historical facts of the concentrator operations, it might be of interest to discuss briefly the problems which confronted the lead-smelting industry of this territory from 1918 until the introduction of selective flotation methods. The oxidized silver ores contained excess quantities of silica and the zinc content of the lead-silver sulphide ores was increasing. The elimination of silica and zinc in lead blast furnace operations required fluxing with iron, but it was difficult to obtain suitable iron ores for this purpose. A careful survey of the situation by the geological department in conjunction with the flotation testing laboratory staff revealed that a selective flotation process would accomplish: (1) The elimination of silica from the lead-silver sulphide ores; (2) the removal of zinc from many ores into a separate concentrate, thus bringing a revenue rather than a penalty to the shipper; (3) the production of an iron concentrate from the pyrite content of the sulphide ores; and (4) the mining of lower-grade ore deposits heretofore considered unprofitable.

With these possibilities in mind, the company pioneered in the establishment of a central custom mill in 1924, purchasing lead-zinc ores on schedules based upon the actual recoveries made and grades of concentrates produced. At this time the company was operating a 1,000-ton-capacity copper flotation concentrator treating the ore from the Utah Delaware mine in two 500-ton-capacity sections. In order to treat approximately 500 tons of lead-zinc iron ores per day it was necessary to use the fine-grinding unit of one 500-ton section and to rearrange the entire Callow equipment into a suitable flow sheet for the operation of three different circuits; namely, lead, zinc, and iron. Installation of additional concentrate thickening and filter equipment was also necessary.

The capacity of the concentrator was increased 500 tons per day early in 1925. Minerals Separation Sub-Aeration machines were selected for the flotation equipment of this addition. The present flow sheet of the mill uses both Callow and Minerals Separation in each section rather than entire sections of each type.

PRESENT CONCENTRATOR PRACTICE

A flow sheet of the crushing plant is given in figure 1; figures 2 and 3 present flow sheets of fine grinding and flotation of section 1, respectively. The treatment in section 2 is similar to that of section 1, except that two 14-cell, 18-inch Minerals Separation machines are used in the zinc rougher circuit in place of the 4-cell M. S. conditioner and four 8-pan Callow cells as shown in figure 3.

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HANDLING AND MINING OF ORES

Custom ores are crushed and sampled at the smelter sampling mill. The final product, which is discharged from a Symons cone crusher set at a 3/8-inch opening, is conveyed to one of 10 storage bins having a total capacity of 2,250 tons.

Mixtures are made of the various ores according to the amenability of the individual ores to the general reagent combination as applied to the basic ore being treated at that time, predetermined by batch laboratory tests or previous treatment at the concentrator. The ores entering the mixture are fed from the storage bins onto a long conveyor belt extending the entire length of the bins and discharged into 50-ton-capacity, bottom-dump railroad cars, which are later dumped into a receiving pocket at the concentrator. From the receiving pocket the ore is conveyed and elevated to either section 1 or 2 ball mill feed bins, thereby by-passing the concentrator crushing equipment.

Gravity-mill products received from other mills are first pipe-sampled and then introduced into the regular mill feed, by loading small amounts on the mixture cars by a locomotive crane.

Company account ores shipped from Bingham over the aerial tramway are dumped and crushed at the concentrator. Every fifth bucket, however, is sent to the smelter sampling mill for weighing and sampling.

CRUSHING

Referring to figure 1, apron feeders deliver the ore from the coarse-ore bins at the concentrator to a 30-inch inclined conveyor at the rate of 125 tons per hour. The conveyor is direct driven by a 25-hp. motor and discharges onto a stationary grizzly having 2-inch spaces. The grizzly oversize passes to a no. 6 Telsmith gyratory crusher with the discharge set at approximately 2 inches. The average life of the manganese-steel mantle and concaves, when handling 575 tons of ore per day, is 2-1/2 years.

The grizzly undersize and crusher product are conveyed to a 30-inch elevator equipped with a double row of 14- by 7-inch manganese-steel buckets, which discharges over two 4- by 6-foot Mitchell Hum-mer screens having 1-1/4-inch holes.

The screen undersize goes to the ball-mill feed bins and the oversize goes to a set of 54- by 20-inch Traylor heavy-duty rolls. The rolls shells are made of forged steel and show a consumption of 0.024 pound per ton of ore crushed. The rolls are operated at a speed of 95 r.p.m. and are belt driven from a line shaft which also drives the crusher. A 150-hp. motor is used for operating the crusher and rolls.

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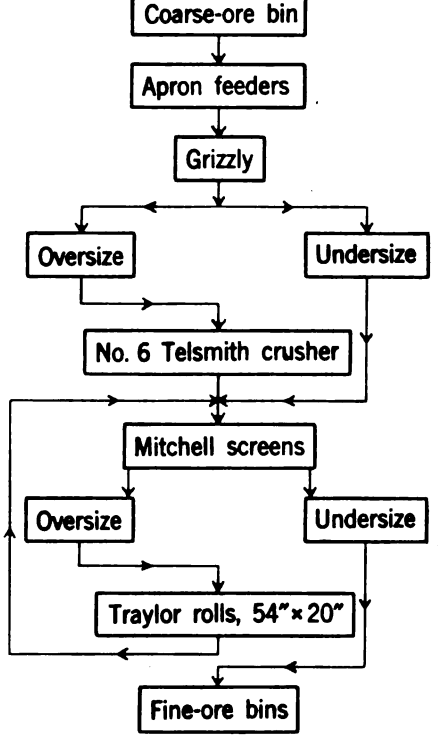

Figure 1.—Flow sheet of crushing plant.

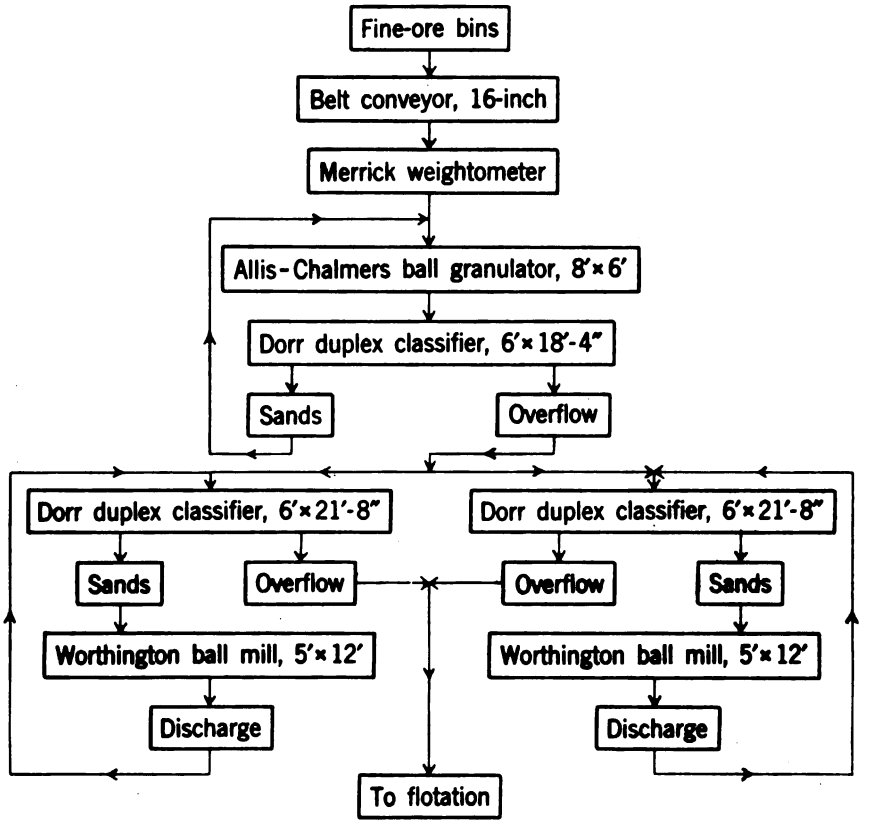

Figure 2.—Flow sheet of grinding plant.

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FINE GRINDING

Referring to figure 2, the fine grinding equipment of each 500-ton section is identical and is of the two-stage type. Each section has a 650-ton-capacity fine-ore bin from which feed is drawn by means of ratchet-driven belt feeders discharging onto a 16-inch conveyor belt. The ore is carried by this belt over a Merrick weightometer to the double-scoop feeder of an 8- by 6-foot Allis-Chalmers grate-discharge ball mill, which operates in closed circuit with a 6-foot by 18-foot 4-inch Dorr duplex classifier and constitutes the primary grinding circuit. The overflow from the primary classifier is equally divided between two secondary 6-foot by 21-foot 8-inch Dorr duplex classifiers, each operating in closed circuit with a 5- by 12-foot Worthington ball mill. The overflow from the secondary classifiers comprises the flotation feed.

The primary mills are operated at a speed of 18.7 r.p.m. and are driven by 200-hp. induction motors, connected by means of Link-Belt drives. Cast-iron balls, 3-inch diameter, are used and are manufactured at the foundry of the Anaconda Copper Mining Co. at Anaconda, Mont. Ball loads amount to 27,000 pounds. Feed end and shell liners are made of manganese steel and the grate sections are made of tool steel. Pulp density in the primary mills is maintained between 72 and 75 percent of solids.

The secondary mills operate at a speed of 27.2 r.p.m. and are driven by 100-hp. induction motors, as well as through Link-Belt silent-chain drives. Balls used are 2-inch cast iron, also manufactured at Anaconda, Mont. Ball loads carried are 14,000 pounds per mill. Feed end and shell liners are made of hard white iron. Pulp density in the secondary mills is maintained between 68 and 70 percent of solids.

The following tabulation shows liner and ball consumptions, in pounds per ton of primary mill feed, for the primary and secondary mills:

	Liners and grates	Balls
Primary mills, pounds	0.30	2.30
Secondary mills, pounds	.20	1.14

Screen analyses of grinding-circuit products are given in table 1. It should be noted that the figures given in table 1 represent a period in which extra fine grinding was practiced. More typical examples of screen sizes of classifier overflow and flotation tailing are presented in table 2.

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Table 1. - Screen analyses of grinding-circuit products

Screen size, mesh	Weight, percent						
	Primary ball mill feet	Primary classifier sands	Primary ball mill discharge	Primary classifier overflow	Secondary classifier sands	Secondary ball mill discharge	Secondary classifier overflow
+ 48	75.3	61.0	30.2	12.7	14.4	1.5	—
+100	6.0	23.7	19.7	20.4	33.4	8.7	3.9
+200	4.8	7.6	13.9	15.7	28.3	22.6	12.6
-200	14.9	7.7	36.2	51.2	23.9	67.2	83.5

Table 2. - Typical screen analyses

Screen size, mesh	Weight, percent	
	Secondary classifier overflow	Flotation tailing
+ 65	1.0	2.0
+100	5.6	9.0
+150	7.4	12.0
+200	11.6	14.6
-200	74.4	62.4

CLASSIFICATION

The 6-foot by 18-foot 4-inch primary classifiers have a slope of 3-1/2 inches per foot and operate at a rate of 26 strokes per minute. The 6-foot by 21-foot 8-inch secondary classifiers slope 2-3/4 inches per foot and their rakes operate at a speed of 22 strokes per minute. The secondary classifier overflow pulp which is flotation feed is maintained between 22 and 24 percent of solids.

FLOTATION

Referring to figure 3, the secondary classifier overflow pulp from each grinding section is conveyed by launder directly to flotation. Present practice follows the use of two 14-cell 18-inch Minerals Separation Sub-Aeration machines for the lead circuit roughers of each section. The zinc rougher circuit of section 1, as previously described, consists of four 8-pan Callow cells, while the zinc rougher circuit of section 2 employs two 14-cell 18-inch Minerals Separation Sub-A. machines. Callow cells are used in the iron rougher circuits of both sections and also for cleaning all lead, zinc, and iron rougher concentrates produced in either section.

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The line shaft of each M. S. machine is driven by a 40-hp., silent chain drive at a speed of 380 r.p.m. The spindle shafts are driven at a speed of 331.3 r.p.m. from the line shaft through bevel gears. The peripheral speed of impellers is 1,560 feet per minute.

Impellers are 18 inches in diameter, full double-disk type and are made of hard white iron. Their average life is 5 to 7 months, depending upon whether in lead- or zinc-circuit service.

Callow cell pans are the standard 3- by 3-foot type equipped with 3-ply 18-ounce canvas blankets. Average life of cell blankets is 90 days.

Rougher lead concentrate is removed from the first four to six cells of the M. S. machines and cleaned in a 3-pan Callow cell. The cleaner tailing, together with the froth from the remaining cells of the M. S. rougher machines, is returned by bucket elevator to the head of the lead circuit. Tailing pulp from the lead circuit is pumped to a 30-foot Dorr thickener from which the underflow is conveyed by gravity to the head of the zinc-rougher circuit. The Dorr thickener functions as a pulp conditioner, giving the pulp a longer time of contact with flotation reagents, and also as a regulator of the density of the feed to the zinc circuit.

Steam is introduced into the lead-circuit tailing pulp before it enters the zinc-rougher cells. The temperature of the pulp in the zinc circuit is maintained at about 30° C.

In section 1, a conditioner is provided between the Dorr thickener and the Callow zinc circuit. The conditioner is a 4-cell, standard M. S. machine, with 24-inch cruciform agitators driven by a 25-hp. motor through Tex-ropes. The flow sheet of section 2, which employs M. S. Sub-A. machines in the zinc circuit, contains no conditioner between the Dorr thickener and the zinc circuit.

The froths from the first 3 pans of each Callow zinc rougher are combined and double-cleaned in 6-pan Callow cells. The froths from the first four to six cells of each of the section 2 zinc rougher machines are combined and double-cleaned in two 3-pan Callow cells.

Middling and cleaner tailing from the zinc circuits of each section join the tailing from the rougher lead circuits of their respective sections and are pumped to the 30-foot Dorr thickeners previously mentioned.

Tailing from the zinc-rougher circuit of each section comprises the feed to the iron circuit. In section 1, rougher-iron concentrates are taken from the first four pans of each of two parallel 12-pan Callow cells. The rougher concentrate is cleaned in a 6-pan Callow cell. Rougher-iron concentrates in section 2 are taken from the first 3 pans of each of two parallel 8-pan Callow cells and cleaned in a 6-pan cell. Middling and cleaner tailing are returned to the head of the iron circuit of each section. Tailing from the iron circuits of each section is thickened and sent to the tailing disposal pond.

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REAGENTS

Soda ash is used in amounts of from 0.1 to 2.0 pounds per ton of ore as a conditioning reagent. It is added to the primary ball mill and to the lead-circuit tailing.

Sodium cyanide is fed to the primary ball mill as a 20 percent solution, in amounts of from 0.2 to 0.3 pound per ton of ore.

Zinc sulphate is fed to the primary ball mill as a 15 percent solution in amounts varying from 0.6 to 1.5 pounds per ton of ore.

Sodium aerofloat is fed dry to the primary ball mill in amounts of 0.1 pound or less per ton of ore.

Potassium ethyl xanthate is fed as a 15 percent solution to the heads of the lead and zinc circuits in amounts of 0.03 to 0.04 pound per ton of ore and to the head of the iron circuit in amounts of 0.15 to 0.30 pound per ton of ore.

Aerofloat No. 15 is used at an average rate of 0.15 pound per ton of ore as a collector and frother in the zinc circuits.

Copper sulphate is added dry, in fine crystalline form, to the lead tailing ahead of the zinc circuit at the rate of 1.25 to 1.50 pounds per ton.

Potassium amyl xanthate is fed to the iron circuit as a 15 percent solution.

All flotation reagents which are fed in aqueous solution are distributed from disk-and-cup feeders, there being a separate feeder for each point of addition. Aerofloat is fed from either disk-and-cup or Geary feeders. Dry reagents, such as copper sulphate, soda ash, and sodium aerofloat are fed from belt-and-hopper feeders.

BLOWERS

Three No. 6-1/2 Roots blowers, two of which are operated at a time, furnish air for the Callow and Minerals Separation Sub-Aeration flotation equipment and the Oliver filters.

These blowers each have a capacity of 5,200 cubic feet of air per minute at 4-1/2 pounds' pressure. The air is distributed to the Callow cells and Oliver filters at a pressure of 4-1/2 pounds per square inch and to the M. S. machines at 16 ounces per square inch. Average volumes of air used are 7 cubic feet per minute per square foot of Callow cell pan area and 20 cubic feet per minute per cell for the M. S. machines.

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The blowers are located in the grinding division of the concentrator and are all connected to a main header pipe from which air is distributed to the flotation and filtering divisions. Each blower is belt driven by a Lenix drive at a speed of 225 r.p.m. by a 150-hp. induction motor.

METALLURGICAL RESULTS

Average analyses of heads and products of flotation operations and average recoveries are given in table 3. Metallurgical data for February 1931 are presented in table 4.

DEWATERING AND HANDLING CONCENTRATES

The equipment for concentrate thickening includes three 30- by 10-foot and one 40- by 10-foot Dorr thickeners. One of the 30- by 10-foot thickeners handles lead concentrates from both sections, another of the same size is used for the iron concentrate, and the 40- by 10-foot thickener is used for the zinc concentrates of both sections. A spare 30- by 10-foot thickener is available for emergency use or for the separate thickening of any product from either section if desired.

The pulp density of the concentrate pulps entering their respective thickeners is approximately 20 percent of solids. Thickened pulps containing 50 to 60 percent of solids are elevated to Oliver drum-type filters. The thickener overflows are combined and form an important portion of the return circuit water.

The filtering equipment consists of four 12- by 10-foot and one 12- by 12-foot Oliver drum-type filters. It is seldom necessary to use more than one of these filters for each concentrate. However, the two extra filters permit the filtering of special concentrates and eliminate lost time in operation when repairs are necessary.

It is customary to thicken and filter a portion of the iron concentrate with the lead concentrate, the amount depending upon that desired for sintering and fluxing operations at the smelter.

The moisture content of the filtered concentrates follows:

	Percent moisture
Zinc concentrate	5.3 to 10.0
Lead-iron concentrate	6.5 to 9.5
Iron concentrate	7.5 to 10.0

The variation in moisture content is due to the character of the gangue in the ore treated. The filters are operated at a speed of one revolution in 10 minutes and have an average capacity of 800 pounds per square foot per 24 hours.

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Table 3. - Average analyses of flotation products and mill recoveries

	Weight, percent	Analyses: Percent: Lead	Copper	Zinc	Iron	Insoluble	Ounces per ton: Gold	Silver	Recovery or distribution, percent: Lead	Copper	Zinc	Iron	Gold	Silver
Heads	100.00	8.62	0.42	11.23	9.75	—	0.137	7.10	100.00	100.0	—	--	100.00	100.00
Lead concentrate	12.60	64.02	2.00	7.67	3.83	3.33	.539	44.65	93.62	60.8	8.61	4.96	49.71	79.26
Zinc concentrate	16.41	1.19	.65	58.44	3.28	2.50	.116	3.67	2.26	25.8	85.44	5.52	13.86	8.49
Iron concentrate	15.74	.80	.18	2.71	41.50	5.37	.188	2.85	1.47	6.7	3.80	67.00	21.64	6.31
Final tailing ..	55.25	.41	.05	.44	3.98	—	.037	.76	2.65	6.7	2.15	22.52	14.79	5.94

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Table 4. - Metallurgical data for February 1931

Total ore treated	tons	10,434.20
Days operated		23
Hours operated per day		19.26
Average ore treated per 24 hours operating time	do.	565.29
Average number of sections operating		1
Total lead concentrate produced	do.	1,315.18
Average lead concentrate produced per 24 hours	do.	71.25
Total zinc concentrate produced	do.	1,712.62
Average zinc concentrate produced per 24 hours	do.	92.78
Total iron concentrate produced	do.	1,642.11
Average iron concentrate produced per 24 hours	do.	88.96
Total concentrates produced	do.	4,669.91
Average concentrates produced per 24 hours	do.	252.99
Ratios of concentration, tons into 1:		
Lead circuit		7.93
Zinc circuit		6.09
Iron circuit		6.35
Combined circuits		2.23
Consumption of reagents per ton of ore treated	pounds	
Soda ash		1.85
Sodium aerofloat		.065
Sodium cyanide		.217
Zinc sulphate		.738
Copper sulphate		1.379
Aerofloat No. 15		.100
Potassium ethyl xanthate		.314
Potassium amyl xanthate		.115

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A vacuum of 21 inches of mercury is maintained by two 22- by 8-inch Ingersoll-Rand type ER-1 vacuum pumps. Air for blowing is furnished by the flotation blowers at 4-1/2 pounds' pressure per square inch.

Filter covers are of Palma twill canvas cloth and have an average life of 75 days.

The filter cake is discharged directly into railroad cars. Filtrate water is reclaimed and used in the return circuit water.

DISPOSAL OF TAILINGS

The final tailings from both sections, amounting to about 50 percent of the weight of ore treated, are conveyed by launder to a 100-foot diameter Dorr thickener and thickened from 15 to 50 percent of solids. The overflow water amounting to approximately 350 gallons per minute is added to the return water circuit. The thickened tailing pulps are elevated by a 4-inch Wilfley pump to a launder and flow by gravity to impounding ponds located about 1-1/2 miles below the concentrator. No attempt is made to reclaim any water from these ponds.

SAMPLING

During each shift samples are taken of heads, lead concentrate, zinc concentrate, iron concentrate, and tailing of each section with standard automatic samplers. These samples are assayed daily for the purpose of metallurgical control and guidance.

WATER SUPPLY

Fresh water, as previously stated, is obtained from mountain springs and has the following analysis:

	Grains per U. S. gallon
Organic matter	7.47
Fe_2O_3 and Al_2O_3	.35
SiO_2	.58
CaO	6.88
MgO	3.73
SO_3	5.13
Total solids	32.67

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The consumption of fresh water for metallurgical purposes amounts to approximately 115 gallons per minute or is at a rate of 144 gallons per minute with a feed rate of 1 ton of ore per minute. This amount corresponds closely to the loss of water in the thickened tailing pulp and as moisture in the concentrates. The introduction of fresh water is chiefly as spray water in the rougher lead and zinc concentrate launders.

All possible water is reclaimed from thickening and filtering operations and concentrated at a convenient elevation, from which it is pumped to two equalizing tanks located above the mill at an elevation sufficient to permit its use in any division.

Two 6-inch Cameron pumps are used for circulating the return water, each of which is direct-driven by a 50-hp., 1,735 r.p.m. motor.

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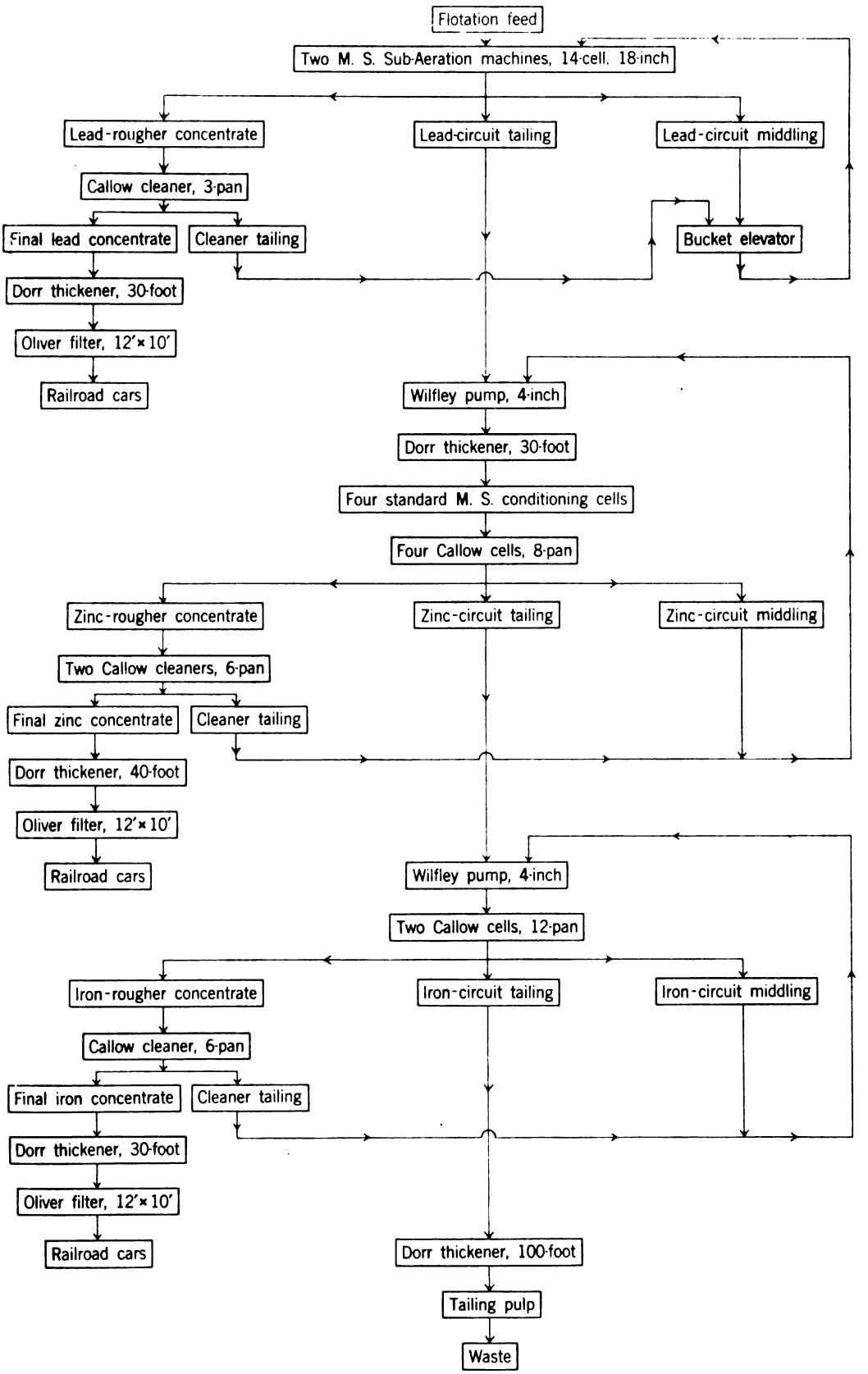

Figure 3.—Flow sheet of flotation and dewatering of section 1.

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